COLORADO STATE UNIVERSITY PROGRAM FOR
DEVELOPING, TESTING, EVALUATING AND OPTIMIZING
SOLAR HEATING AND COOLING SYSTEMS

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RATING AND CERTIFICATION OF DOMESTIC WATER HEATING HEATING SYSTEMS

Integral Collector Storage

Irradiated testing of the integral collector storage system, using the indoor simulator, has been completed. Various TRNSYS runs were made with the data obtained during testing. Results of all ICS tests (irradiated and heat loss) are summarized in Alison Mason's Master's Thesis, which was presented at SEAL on August 6. To highlight, new ($\tau \alpha$) information on the ICS was obtained and a modified TRNSYS model (one that included two separate banks of tubes) was found to give performance results much closer to the experimental ones.

Development of off-normal indoor simulation tests of the ICS collector system will be delayed in order to develop testing strategies for the Solahart thermosyphon system.

Thermosyphon

Carl Bickford will carry out the work involved in testing the thermosyphon system. A literature search is underway, and current TRNSYS modeling of such systems is being reviewed. An experimental test plan will be developed in the latter part of September.

UNIQUE SOLAR SYSTEM COMPONENTS

Heat Exchanger Modeling

Typically, the effectiveness of the heat exchanger in an indirect solar domestic hot water (SDHW) system is known (at most) at the manufacturers recommended operating flow rates. The variation of heat exchanger effectiveness with flow rate is not known. The heat exchanger effectiveness is therefore held constant at this value when the system is simulated.

In order to illustrate the errors that can occur when a constant heat exchanger effectiveness assumed, an analytical model of a concentric tube heat exchanger typical of those used in SDHW systems has been created. The performance of an SDHW system incorporating this heat exchanger has been calculated for collector and recirculation flow rates ranging from zero to twice the nominal flows. The instantaneous Q_u is obtained using a constant heat exchanger effectiveness (independent of the flow rates), a constant heat exchanger overall conductance, UA , (independent of the flow rates), and the calculated variation in the heat exchanger effectiveness with collector and recirculation flow rates. The results are compared to illustrate the magnitude of the errors that may result at off-nominal flow conditions. The magnitude of this error may be reduced by calculating the heat exchanger conductance and fixing this value (instead of the heat exchanger effectiveness). Similar comparisons made for the integrated daily performance of SDHW system, show a smaller disagreement. A paper for the 1994 ASME Solar Conference documenting these results is being prepared.

The TRNSYS model of the indirect SDHW system developed for the calculations above has also been used to obtain a preliminary model comparison to experimental data obtained from Thornbloom et al. (1992 and 1993). The heat exchanger modeled analytically above is based loosely on the heat exchanger employed in Thornbloom's experiments. The preliminary comparisons identified two modeling problems. First, the pump parasitic energy measured in the experiments was much lower than the name plate rating of the pumps used initially in the experiments. Second, the TRNSYS Type 4, Stratified Storage Tank model did not accurately simulate the auxiliary tank performance. This error may have two possible sources; the TRNSYS tank model will not model two auxiliary heating elements and will not allow the auxiliary heater to be placed in the bottom node of a multiple node tank. The Type 4, Stratified tank model has been modified and detailed comparisons with the experimental data will be conducted to test these modifications.

Integrated Tank/Heat Exchanger Modeling/Experiments

Jeff Miller's, the graduate student research assistant conducting this work, prepared and presented a written research proposal as part of his preliminary exam held on August 10, 1993. The research proposal reviewed the state of the art in tank models and efforts to experimentally validate these models, outlined the need for further research, and presented a brief proposal for developing a valid model for the wrap-around heat exchanger tank. An instrumentation and test plan is being developed.

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Heat Exchanger/Solar Storage Tank Bibliography

A bibliography of relevant heat exchanger and SDHW storage tank references has been compiled in the course of this research. Copies have been distributed to NREL, FSEC, ASU/SRCC, and UW.

References

Thornbloom, M. D., *Impact of Flow Rates and Heat Exchanger Design on Indirect Solar Water Heating System Performance*, Masters Thesis, Colorado State University, Fort Collins, CO, 1992.

Thornbloom, M. D., and J. H. Davidson, "Influence of Heat Exchanger Effectiveness and System Flow Rates on Experimental Rating of a Generic Antifreeze SDHW System," *1992 ASES Solar Conference*, Cocoa Beach, FL., 1992.

ADVANCED RESIDENTIAL SOLAR DOMESTIC HOT WATER (SDHW) SYSTEMS

Several tasks have been completed in the previous few months, the first of which was the disassembly of the three hot water systems that were in the basement of Solar House I. The storage tanks for the three systems have been relocated in Solar House I so as to allow better access for the pipes to and from the collectors, as well as to reduce the overall length of piping needed.

All three systems are being instrumented with thermocouple trees in the storage tanks, pressure transducers, flowmeters, and thermopiles to facilitate accurate measurement of system parameters. Manufacturer's literature has been searched and all of the instrumentation and hardware required has been bought or ordered. We are still awaiting receipt of some hardware. This revised instrumentation plan is shown in figures 2, 3, and 4.

A new design for the thermocouple trees (used to measure the degree of stratification in the water heater tanks) was necessitated so that we would not need to cut a large hole in the top of the water tanks. Cutting through the lining of the tanks will cause them to break and rusting will occur rapidly. Figure 1 shows the design of the new thermocouple tree. An analysis was done to determine whether axial conduction along the brass tubing would be a cause of concern; it is negligible.

FIGURE 1

The piping of the systems has been started and the support structures have been built.

FIGURE 2

NEG, Integral Storage Collector

FIGURE 3

ASN

FIGURE 4

DESICCANT COOLING OF BUILDINGS

During the reporting period, we accomplished the following:

- Selected and developed a simulation input file to get cooling loads profiles for a 20,000-square-foot commercial office building.
- Revised TRNSYS models to include new air-conditioning system control options (ventilation cooling, evaporative cooling on fresh air only).
- Presented additional cost and performance data to SAIC on our proposed desiccant system.

MANAGEMENT AND COORDINATION OF COLORADO STATE/DOE PROGRAM

Coordination of research activities continued on the four technical research tasks under the DOE grant, and accounts were maintained and updated. Financial and technical reports were submitted as required.

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